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viz. γ *Leonis,* which is erroneous by several degrees. The new calculation, compared with Dr. Oppolzer's elements of the comet *Ast. Nach.* 1624, the perihelion passage being reduced to Milan Mean Time is—

	Meteors, 13th Nov.	Comet I, 1866.
Perihelion passage	Nov. 10, 092	Jan. 11, 160
Longitude of Perihelion	56° 25′ 9″	60° 28′ 0″
Node	231 28 2	231 26 1
Inclination	17 44 5	17 18 1
Perihelion distance	0·9873	0·9705
Excentricity	0·9046	0·9054
Semi-axis major	10·340	10·324
Revolution	33·250 years	33·176
Motion	retrograde	retrograde

where it is assumed, 1°, the time of max. of the meteors is Nov. 13 13^{h} 11^{m} Greenwich M.T.; 2°, the position of the radiant point, long. 143° 12′, lat. N. 10° 16′; 3°, period 33·25 years (Newton). The position of the radiant point is that determined by Mr. Herschel, *Monthly Notices*, vol. xxvii. p. 19; but taking the longitude 145° instead of 143° 12′, the discrepancy of 4° in the longitude of perihelion would be made to disappear." M. Schiaparelli asks, Are the meteors to be considered as swarms of minute comets, or as the products of the dissolution of large comets?

On the Orbit of the November Meteors. By Prof. J. C. Adams.

It is known to the President and to several members of the Society that I have been for some time past engaged in researches respecting the November Meteors, and allusion is made to some of my earlier results in the last Annual Report. As my investigations are now in some measure complete, and the results which I have obtained appear to me important, I have thought that they may not be without interest for the Society.

In a memoir on the November Star Showers, by Professor H. A. Newton, contained in Nos. 111 and 112 of *The American Journal of Science and Arts*, the author has collected and discussed the original accounts of 13 displays of the above phenomenon in years ranging from A.D. 902 to 1833.

The following table exhibits the dates of these displays, and the Earth's longitude at each date, together with the same particulars for the shower of November last, which have been added for the sake of completeness.

No.	A D.	Day and hour.	Earth's longitude.
		d h	° ′
1	902	Oct. 12 17	24 17
2	931	14 10	25 57
3	934	13 17	25 32
4	1002	14 10	26 45
5	1101	16 17	30 2
6	1202	18 14	32 25
7	1366	22 17	37 48
8	1533	24 14	41 12
9	1602	27 10 O.S.	44 19
10	1698	Nov. 8 17 N.S.	47 21
11	1799	11 21	50 2
12	1832	12 16	50 49
13	1833	12 22	50 49
14	1866	13 13	51 28

From these data Professor Newton infers that these displays recur in cycles of 33·25 years, and that during a period of two or three years at the end of each cycle a meteoric shower may be expected. He concludes that the most natural explanation of these phenomena is, that the November Meteors belong to a system of small bodies describing an elliptic orbit about the Sun, and extending in the form of a stream along an arc of that orbit which is of such a length that the whole stream occupies about one-tenth or one-fifteenth of the periodic time in passing any particular point. He shows that in one year the group must describe either $2 \pm \frac{1}{33\cdot25}$, or $1 \pm \frac{1}{33\cdot25}$, or $\frac{1}{33\cdot25}$ revolutions, or, in other words, that the periodic time must be either 180·0 days, 185·4 days, 354·6 days, 376·6 days, or 33·25 years.

It is seen that the time of the year at which the meteoric shower takes place becomes gradually later and later, and that accordingly the Earth's longitude at that time, or the longitude of the node of the orbit of the meteors, is gradually increasing. Professor Newton finds that the node has a mean motion of $102''\cdot6$ annually with respect to the Equinox, or of $52''\cdot4$ with respect to the fixed stars; and he remarks that since the periodic time is limited to five possible values, each capable of an accurate determination, and since therefore from the position of the radiant point the other elements of the orbit can be found, it seems possible to compute the secular motion of the node for each periodic time with considerable accuracy, and the actual motion of the node being known, we have thus an apparently simple method of deciding which of the five periods is the correct one.

Soon after the remarkable display of these meteors in November last, I undertook the examination of this question. From the position of the radiant point as observed by myself, I calculated the elements of the orbit of the meteors, starting

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with the supposition that the periodic time was 354·6 days, the value which Professor Newton considered to be the most probable one. The orbit which corresponds to this period is very nearly circular, and it readily follows from the ordinary theory that the action of *Venus* would produce an annual increase of about 5″ in the longitude of the node, and that of *Jupiter* an annual increase of about 6″. The calculation of the motion of the node due to the Earth's action, presented greater difficulty in consequence of the two orbits nearly intersecting each other. I succeeded, however, in obtaining an approximate solution, applicable to this case, from which it followed that the Earth's action would produce an annual increase of nearly 10″ in the longitude of the node. Thus the three planets above mentioned which alone, in the case supposed, sensibly affect the motion of the node, would cause a motion of about 21″ annually, or nearly 12′ in 33·25 years. It has been already mentioned that the observed motion of the node is 52″·4 annually, or about 29′ in 33·25 years. Hence the observed motion of the node is totally irreconcilable with the supposition that the periodic time of the meteors about the Sun is 354·6 days. If the periodic time were supposed to be about 377 days, the calculated motion of the node would differ very little from that in the case already considered, while, if the periodic time were a little greater or a little less than half a year, the calculated motion of the node would be still smaller. Hence, of the five possible periods indicated by Professor Newton, four are entirely incompatible with the observed motion of the node, and it only remains to examine whether the fifth period, viz. one of 33·25 years, will give a motion of the node in accordance with observation.

8bre
21″

The calculations which have been above described were entirely founded on my own determination of the radiant point. In order to have as secure a basis as possible for the subsequent calculations, I adopted for the position of the radiant point the mean of my own and five other determinations, partly taken from published documents and partly privately communicated to me. These determinations are as follows, the several authorities being placed in alphabetical order:—

	R.A. °	R.A. ′	Decl. °	Decl. ′	
Adams	148	50	22	10	N.
Baxendell	149	33	22	57	
Brünnow	150		22		
Challis	149	39	23	12	
Herschel	148	9	23	48	
Herschel A.	149		24		
Mean	149	12	23	1	N.

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Or with reference to the ecliptic,

Long. 143° 22′ Lat. 9° 51′ N.

Starting from this position of the radiant point, and the assumed period, and taking into account the action of the Earth on the meteors as they were approaching it, I obtained the following elliptic elements of their orbit:—

Period	33·25	years (assumed)
Mean distance	10·3402	
Excentricity	0·9047	
Perihelion distance	0·9855	
Inclination	16° 46′	
Longitude of Node	51 28	
Distance of Perihelion from Node	6 51	
Motion Retrograde		

In order to determine the secular motion of the node in this orbit, I employed the method given by Gauss in his beautiful investigation "*Determinatio attractionis &c.*"

It may be proved that if two planets revolve about the Sun in periodic times which are incommensurable with each other, the secular variations which either of these bodies produces in the elements of the orbit of the other would be the same as if the whole mass of the disturbing body had been distributed over its orbit in such a manner that the portion of the mass distributed over any given arc should be always proportional to the time which the body takes to describe that arc. In the memoir just referred to, Gauss shows how to determine the attraction of such an elliptic ring on a point in any given position. When this attraction has been calculated for any point in the orbit of the meteors, we can at once deduce the changes which it would produce in the elements of the orbit, while the meteors are describing any given small arc contiguous to the given point. Hence, by dividing the orbit of the meteors into a number of small portions, and summing up the changes corresponding to these portions, we may find the total secular changes of the elements produced in a complete period of the meteors.

In this manner I have found that during a period of 33·25 years, the longitude of the node is increased 20′ by the action of *Jupiter*, nearly 7′ by the action of *Saturn*, and about 1′ by that of *Uranus*. The other planets produce scarcely any sensible effects, so that the entire calculated increase of the longitude of the node in the above-mentioned period is about 28′.

As already stated, the observed increase of longitude in the same time is 29′. This remarkable accordance between the results of theory and observation appears to me to leave no doubt as to the correctness of the period of 33·25 years.

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In order to attain a sufficient degree of approximation it is requisite to break up the orbit of the meteors into a considerable number of portions, for each of which the attractions of the elliptic rings corresponding to the several disturbing planets have to be determined; hence the calculations are necessarily very long, although I have devised a modification of Gauss's formulæ which greatly facilitates their application to the present problem. In these numerical calculations I have been greatly aided by my assistants, more especially by Mr. Graham. I am now engaged in obtaining a closer approximation by subdividing certain parts of the orbit of the meteors into still smaller portions, but the results which have been given above cannot be materially changed.

Since I entered upon the foregoing investigation other astronomers have been led, on totally independent grounds, to conclusions which strongly confirm, and are confirmed by, those at which I have myself arrived.

In the *Bullettino Meteorologico dell' Osservatorio del Collegio Romano*, vol. v. Nos. 8, 10, 11, 12, are published four letters from Sig. Schiaparelli, Director of the Observatory of Milan, "*Intorno al corso ed all' origine probabile delle Stelle Meteoriche.*" In these letters the author arrives at the conclusion that the orbits which the meteors describe about the Sun are very elongated, like those of comets, and that probably both these classes of bodies originally come into our system from very distant regions of space. In his last letter, dated 31st Dec. 1866, Sig. Schiaparelli shows that if the August Meteors be supposed to describe a parabola, or a very elongated ellipse, the elements of their orbit calculated from the observed position of their radiant point, agree very closely with those of the orbit of Comet II. 1862, calculated by Dr. Oppolzer. The following table exhibits this agreement:—

	August Meteors.	Comet II. 1862.
Perihelion distance	0·9643	0·9626
Inclination	64° 3′	66° 25′
Longitude of Perihelion	343 28	344 41
Longitude of Node	138 16	137 27
Direction of Motion	Retrograde	Retrograde

Hence it appears probable that the great Comet of 1862 is a part of the same current of matter as that to which the August Meteors belong.

In the letter which has just been referred to, Sig. Schiaparelli likewise gives approximate elements of the orbit of the November Meteors, calculated on the supposition that the period is 33·25 years; but as the calculations were founded on an imperfect determination of the radiant point, these elements were not sufficiently accurate, and Sig. Schiaparelli

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failed to find any cometary orbit which could be identified with that of the meteors.

Soon after this, on the 21st January, 1867, M. Le Verrier communicated to the Academy of Sciences a theory of the origin and nature of shooting stars, very similar in its main features to that of Sig. Schiaparelli, and at the same time gave more accurate elements of the orbit of the November Meteors, his calculations being based on a better determination of the radiant point than that employed by the astronomer of Milan.

In the *Astronomische Nachrichten*, of the 29th January, Mr. C. F. W. Peters of Altona pointed out that the elements given by M. Le Verrier closely agreed with those of Tempel's Comet (I. 1866), calculated by Dr. Oppolzer, and on the 2nd February, Sig. Schiaparelli, having recalculated the elements of the orbit of the meteors on better data than before, himself noticed the same agreement.*

Dr. Oppolzer's elements of Tempel's comet are as follows:—

Period	33·18 years
Mean distance	10·3248
Excentricity	0·9054
Perihelion distance	0·9765
Inclination	17° 18′
Longitude of Node	51 26
Distance of Perihelion from Node	9 2
Direction of Motion	Retrograde.

If these elements be compared with those of the November Meteors which I have given in a former part of this communication, it will be seen that their agreement is remarkably close.

The curious and unexpected resemblance which is thus shown to exist between the orbits of known comets and those of the meteors, both of August and November, opens a wide field for speculation. It is difficult to believe that the coincidences which have been noticed are merely accidental; but whether or not we are disposed to adopt the ideas of Sig. Schiaparelli as to the intimate relations between meteors and comets, I cannot help thinking that my researches respecting the motion of the node of the November Meteors have settled the question as to the periodic time of these bodies beyond a doubt.

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* See *ante*, p. 246.—*Ed.*